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ADVANTAGES FROM MIXED STORAGE OF AMMUNITION

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In a similar manner, the NATO document,[2] Part 1 (Corrigendium No. 3) states in paragraph 305b: "Ammunition and explosives of different compatibility groups may be stored in the same building, if special circumstances require such combinations. Prior approval must be obtained from the appropriate authorities of the nation concerned." Furthermore, from the same document, Part II original in paragraph 507a dealing with field storage, subparagraph 1, states: "Items of compatibility groups C, D, and E may occupy the same site."

Because of the statements quoted from References 1 and 2, it seems logical to store mixes of the munitions listed in Table 1 if the case can be made that the probability of accident is not increased nor the magnitude of an accident should one occur. For the list of munitions considered, all but one are group D if stored without their own means of initiation. The remaining item is the kinetic energy cartridges which are group C. Both documents indicate that group C ammunition may be stored with group D ammunition if conditions justify it.

In assessing the magnitude of an accident, unless it can be shown that the propellant does not participate, the net equivalent weight should be considered as the sum of the total weights of explosive and propellant present.[1] The rationale distinguishing group C from group D compatibility appears to be the separation of propellant from high explosive, but since groups C and D may be mixed under certain conditions, it seems that there is minimal risk in mixing these groups. It would be foolish, perhaps, to mix bulk propellant with group D ammunition, but we are considering mixing group C ammunition packaged one round per fiber container, 2 containers per box, 15 boxes per pallet with palletized group D ammunition. It is difficult to see how this configuration of group C ammunition could increase the probability of an accident or conversely how the group D ammunition increases the probability of an accident. Therefore, while mixed storage of these munitions may not be the ideal storage configuration, it is apparent that if better utilization of existing magazines can be achieved the requirement to justify mixed storage has been met.

One further caveat exists which must be addressed; it relates to the different requirements for citing propellant magazines and explosive magazines. These requirements are delineated in Reference 1, Chapter 17. Examination of Tables 17-6 (and note j of that table), 17-7, and 17-10 from Reference 1 indicates that for the cases considered in this report no problems exist. Because the requirements are different, care should be taken to be certain that host country requirements as well as US requirements are considered with regard to mixing propellant and explosive stores.

III. APPROACH.

Before proceeding further, it is necessary to define two terms which simplify discussion, with apologies to grammarians.

1. Weigh out: For a given munition, this term means that the explosive weight limit of a magazine is exceeded before the magazine is filled with the munition.

2. Cube out: For a given munition, this term means the magazine is filled to capacity before the explosive weight limit is reached.

The major constraints upon actual storage configurations are:

1. Munitions will be stored in their shipping pallets.

2. Access by forklift must be maintained.

3. "Aisles shall be maintained so that units in each stack may be inspected and inventoried..."[1]

4. For mixed storage, each munition must be available for removal without disturbing other stored munitions.

In this paper, two magazine types and six munitions are considered as well as two explosive weight limits for each magazine. The two magazines are a Stradley and a German design which is a rectangular, parallelepiped 60 ft x 40 ft x 15 ft high, with weight limits of 275,000 lbs (125,000 Kg) and 165,000 lbs (75,000 Kg). These were values suggested by an interested user along with the selection of ammunition listed in Table 1.

The first step is to prepare a scale plan view of the rectangular magazine and an end elevation view of the Stradley magazine. Then, working from pallet dimensions, determine a stacking arrangement that meets all the previously mentioned requirements and determine the number of pallets that can be fitted in each magazine for each munition. Then calculate the number of pallets of each ammunition required to reach the explosive weight limit for each magazine and each explosive weight limit. If the number of pallets required to reach the explosive weight limit is less than the magazine capacity, that munition "weighs out." Next, divide the number of pallets at weigh out by the number of pallets at capacity to obtain the decimal fraction of capacity used. The data thus calculated are now entered on a table as shown in Table 2. The table also includes the number of rounds per magazine to eliminate differences in quantity per pallet and obtain numbers more useful to the user. Another useful quantity listed in Table 1 is the explosive density which is obtained by dividing the explosive weight per pallet by the pallet volume.

Having put the data in tabular form, it is now possible to determine where gains can be made by using mixed storage of munitions. It is obvious that there can be no gain in total numbers of rounds stored by mixing two kinds of ammunition that "cube out" or two kinds of ammunition that "weigh out." Benefits can be derived from mixing an ammunition that "weighs out" with ammunition that "cubes out." In principle, it is possible assuming two identical magazines to increase the total number of stored rounds if more than 50 percent of the "weigh out" munitions can be stored in less than 50 percent of the available volume of a magazine. This then allows more than 50 percent of the available volume of a magazine for storage of a munition that "cubes out." In practice this is not strictly true, because provision must be made to ensure that both munitions are accessible. Below is listed a step-by-step procedure for determining benefits to be derived.

Step 1. Select a munition that "weighs out" and note if more than half of the weight limit can be stored in less than half the magazine capacity. For example, from Table 1, D544 stored in the rectangular magazine with a weight limit of 165,000 lbs is an excellent candidate. One-half the weight limit only occupies .215 of the capacity.

Step 2. Select a number of pallets greater than one-half the weigh out limit. For example, choose 810 pallets of D544. This is an increase in storage capacity of 22 percent.

Step 3. Calculate explosive weight of 810 pallets and subtract this from explosive limit. Divide the answer by the weight of explosive per pallet of the munition you wish to store with the D544. For our example, we chose D563.

$$165{,}000 - (810 \times 124) = 100{,}440 \text{ lbs}$$

$$\frac{64{,}560}{50} = 1{,}291 \text{ pallets of D563}$$

Step 4. Calculate if the sum of the fractional capacities calculated is less than 1. If it is, make out a magazine loading diagram.

$$\text{D544} \quad \frac{810}{3{,}108} = .26$$

$$\text{D563} \quad \frac{1{,}291}{2{,}016} = .64$$

$$.26 + .64 = .90 < 1.00$$

Therefore, we can proceed. It is close to 1, however, and we may need to cut back on the number of D563 pallets in order to allow access to both munitions.

Step 5. Layout magazine loading diagram maintaining prescribed aisles. See Figure 1 for example. Note that for the example chosen several variations are possible. That is, a larger number of D544 pallets could have been chosen. Considering the explosive weight per pallet, we see that for even two pallets of D544 added six pallets of D563 must be removed. Thus, mixed storage allows a wide variation of ratios of munitions within explosive limit constraints.

For the example chosen it has been demonstrated that mixed storage yields a gain in the D544 155 mm projectiles of 22 percent with a gain of 14 percent for the D563 155 mm projectiles over separate storage in like magazines.

The step-by-step outline with a specific example demonstrates the advantages to be obtained from mixed storage. The ratio between quantities stored of various munitions can be varied within limits to correspond to the requirements of units being supplied. In the example above, it was assumed that the entire space inside the magazine can be utilized. This may not always be the case as structural supports, lights, or other utilities requiring access may require different stacking arrangements. Thus, each magazine munition combination requires preparation of a magazine loading plan. It is also necessary to allow room for material handling equipment to move freely for loading and unloading purposes.

IV. SUMMARY.

For the magazine types and dimensions selected, the kinds of ammunition selected, and the two explosive limits used, some gains can be made by mixed storage. The general rules for maximizing gains are :

1. Select an ammunition that weighs out at a minimum of total capacity.

2. If the option is available, mix storage with an ammunition that cubes out at a net explosive weight well below the weight limit.

Table 3 lists the gains available for each mix where gains can be achieved. No substantial gains are to be made for either magazine type at the 125,00 Kg explosive weight limit. Consequently, they are not shown in the table. The 105 mm KE ammunition is somewhat difficult to achieve gains with when mixed with other munitions because at magazine capacity the net explosive weight is close to the lower explosive weight limit. This is apparent in Table 3 when various munitions are mixed with the KE munition. This option may still be a viable alternative if the ratios of quantities of these ammunitions to be stored is considered. For example, if one needs to store twice as many 8-inch projectiles as KE rounds, mixing the two could be very advantageous.

ACKNOWLEDGEMENT

The review and comments of Mr. Roger Herron of the ARRADCOM Safety Office at the Ballistic Research Laboratory are gratefully acknowledged.

TABLE 1

Ammunition for Storage

Ammunition	Rounds Per Pallet	Pallet Dimensions in ft W	D	H	Explosive Weight lb	Explosive Density lb/ft^3
Projectile D680 8 inch M106 SCG D	6	2.33	1.67	3.33	233	18.0
Projectile D544 155 mm M107 SCG D	8	2.67	1.17	2.33	124	17.0
Projectile D563 155 mm M483 A1 SCG D	8	2.50	1.25	3.42	50	4.7
Cartridge KE 105 mm M392 A2 SCG C	30	3.53	3.33	4.17	360 (Propellant)	7.4
Land Mine Anti Tank K180 M-15 SCG D	45	4.50	3.75	3.58	1,026	17.0
Land Mine Anti Tank K181 M-21 SCG D	36	3.08	2.42	3.83	389	13.6

TABLE 2

Magazine Loading Capacities

Ammunition		60 x 40 x 15 Rectangular			80 x 25 x 14 Stradley		
		Capacity	125,000	75,000	Capacity	125,000	75,000
Projectile D680 8 inch M106 SCG D	#Pallets	1,576	1,180	708	1,140		708
	#Rounds	9,456	7,080	4,248	6,840		4,248
	Fraction Filled		.75	.45			.62
Projectile D544 155 mm M107 SCG D	#Pallets	3,108	2,217	1,330	1,868		1,330
	#Rounds	24,864	17,736	10,640	15,088		10,640
	Fraction Filled		.71	.43			.71
Projectile D563 155 mm M483 A1 SCG D	#Pallets	2,016			1,396		
	#Rounds	16,128			11,168		
	Fraction Filled						
Cartridge KE 105 mm M392 A2 SCG C	#Pallets	444			324		
	#Rounds	13,320			9,720		
	Fraction Filled						
Land Mine Anti Tank K180 M-15 SCG D	#Pallets	328	268	160	203		160
	#Rounds	14,760	12,060	7,200	9,135		7,200
	Fraction Filled		.82	.49			.79
Land Mine Anti Tank K181 M-21 SCG D	#Pallets	612		424	566		424
	#Rounds	22,032		15,264	20,376		15,264
	Fraction Filled			.69			.75

NOTE: Blanks in weight limit columns indicate magazine may be filled to capacity.

TABLE 3

Advantages Available from Mixed Storage at 75,000 Kg Explosive Limit

Munition Mix	60 x 40 x 15 Rectangular	80 x 25 x 14 Stradley
D680 8 inch D563 155 mm	+ 31% + 14%	+ 2% + 20%
D680 8 inch M392 A2 105 KE	+ 8% + 2% - 5% + 1%	+ 2% - 7%
D544 155 mm D563 155 mm	+ 22% + 14%	- -
D544 155 mm M29A A2 105 KE	+ 1% + 25% - 22% + 2% - 22% + 26%	- -
K180 Land Mine M-15 D563 155 mm	+ 28% + 20%	- -
K181 Land Mine M-21 D563 155 mm	+ 11% + 40%	- -

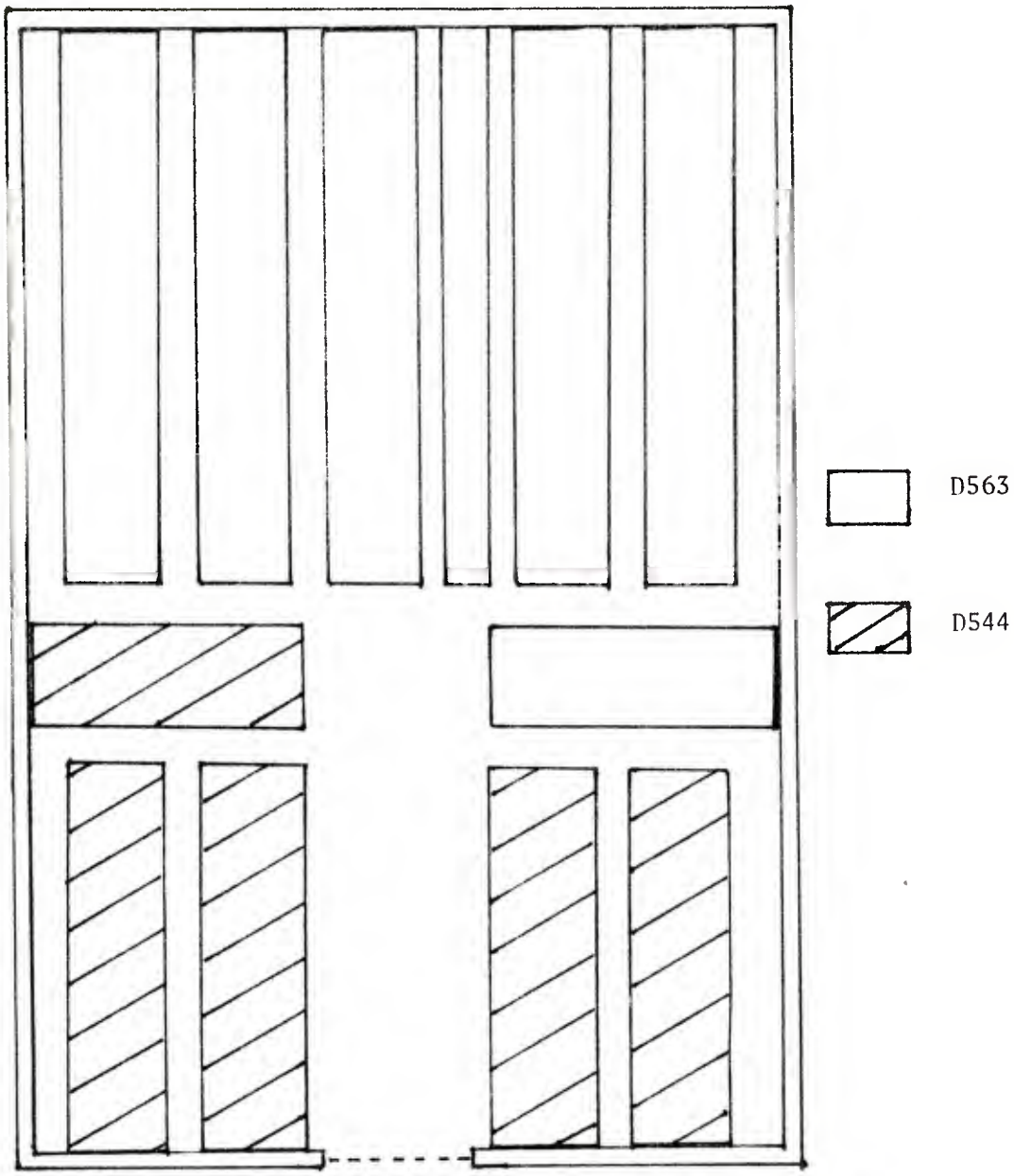

Figure 1. A loading scheme for a 60 x 40 x 15 feet rectangular magazine using mixed storage of D563 155 mm M483A1 and D544 155 mm M107 projectiles. Two magazine storage yields an increased capacity of 14% for D563 and 22% for D544 over separate storage.

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